

INSTRUCTION BOOK FOR

BIRD

**MODEL 43
RF DIRECTIONAL
THRULINE® WATTMETER**

**Also Covers Models
4305, 4330/31, 4430/31, 4521-27, and 43P**

LIMITED WARRANTY

All products manufactured by Seller are warranted to be free from defects in material and workmanship for a period of one (1) year, unless otherwise specified, from date of shipment and to conform to applicable specifications, drawings, blueprints and/or samples. Seller's sole obligation under these warranties shall be to issue credit, repair or replace any item or part thereof which is proved to be other than as warranted; no allowance shall be made for any labor charges of Buyer for replacement of parts, adjustment or repairs, or any other work, unless such charges are authorized in advance by Seller.

If Seller's products are claimed to be defective in material or workmanship or not to conform to specifications, drawings, blueprints and/or samples, Seller shall, upon prompt notice thereof, either examine the products where they are located or issue shipping instructions for return to Seller (transportation-charges prepaid by Buyer). In the event any of our products are proved to be other than as warranted, transportation costs (cheapest way) to and from Seller's plant, will be borne by Seller and reimbursement or credit will be made for amounts so expended by Buyer. Every such claim for breach of these warranties shall be deemed to be waived by Buyer unless made in writing within ten (10) days from the date of discovery of the defect.

The above warranties shall not extend to any products or parts thereof which have been subjected to any misuse or neglect, damaged by accident, rendered defective by reason of improper installation or by the performance of repairs or alterations outside of our plant, and shall not apply to any goods or parts thereof furnished by Buyer or acquired from others at Buyer's request and/or to Buyer's specifications. In addition, Seller's warranties do not extend to the failure of tubes, transistors, fuses and batteries, or to other equipment and parts manufactured by others except to the extent of the original manufacturer's warranty to Seller.

The obligations under the foregoing warranties are limited to the precise terms thereof. These warranties provide exclusive remedies, expressly in lieu of all other remedies including claims for special or consequential damages. SELLER NEITHER MAKES NOR ASSUMES ANY OTHER WARRANTY WHATSOEVER, WHETHER EXPRESS, STATUTORY, OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS, AND NO PERSON IS AUTHORIZED TO ASSUME FOR SELLER ANY OBLIGATION OR LIABILITY NOT STRICTLY IN ACCORDANCE WITH THE FOREGOING.

MODELS COVERED IN THIS INSTRUCTION BOOK

43	4330	4431	4523	4527
43P	4331	4521	4525	
4305	4430	4522	4526	

INSTRUCTION BOOK FOR MODEL 43 RF DIRECTIONAL THRULINE® WATTMETER

**Also Covers Models
4305, 4330/31, 4430/31,
4521-27, and 43P**



BIRD

Electronic Corporation

30303 Aurora Road, Cleveland (Solon), Ohio 44139-2794

Copyright © 1991 by Bird Electronic Corp.

SAFETY PRECAUTIONS

The following are general safety precautions that are not necessarily related to any specific part or procedure and do not necessarily appear elsewhere in this publication.

Keep away from live circuits.

Operating personnel must at all times observe normal safety regulations. Do not attempt to replace parts or disconnect an RF transmission or any other high voltage line while power is applied. When working with high voltage always have someone present who is capable of rendering aid if necessary. Personnel working with or near high voltage should be familiar with modern methods of resuscitation.

Warning: Warning notes call attention to a procedure which, if not correctly performed, could result in personal injury.

Caution: Caution notes call attention to a procedure which, if not correctly performed, could result in damage to the instrument.

The following will appear in the text of this publication and are shown here for emphasis.

Continued

CAUTION

Do not drop the THRULINE® Wattmeter or its elements or subject them to hard blows. The microammeter is shock mounted in the wattmeter housing, but its delicate mechanism may be damaged by severe impact.

WARNING

When operating this equipment in conjunction with RF power of 200 watts or higher, the potential of the center conductor of the RF line section will be 100 volts or higher. Do not contact the center conductor. If cleaning becomes necessary, shut off the RF power.

CAUTION

When making low reflection readings using a more sensitive element, take care to insert the element so that it senses reflected power only. Do not rotate the element in the socket so that it is subjected to forward power. This can result in damage to the Plug-In Element, the microammeter, or both.

WARNING

When using dry cleaning solvents, provide adequate ventilation and observe normal safety precautions. Many dry cleaning agents emit toxic fumes that could be harmful to your health, if inhaled.

TABLE OF CONTENTS

	Page
SAFETY PRECAUTIONS	i
INTRODUCTION	
Purpose and Function	vi
Performance Characteristics and Capabilities	vii
SECTION I - INSTALLATION	
Portability	1
Connections	2
Remote Installation	3
SECTION II - THEORY OF OPERATION	
Travelling Wave Viewpoint	6
Coupling Circuit	6
Standing Wave Ratio VS Reflected/Forward Power Ratio	7
SECTION III - OPERATING INSTRUCTIONS	
General	9
Load Power	10
P vs ϕ and its Significance	11
Measurement and Monitoring of Transmitter Power	16
Testing of Lines, Connectors, Filters, Etc.	16
Frequency Response	18
Impedance Mismatch	19

TABLE OF CONTENTS [CONT.]

Page

SECTION IV - MAINTENANCE

General	27
Cleaning	27
Contact Adjustment	28
Troubleshooting	29
Calibration Checks - THRULINE® vs TERMALINE® Wattmeters	30

SECTION V - REPLACEMENT PARTS LIST

Model 43	34
----------------	----

SECTION VI - DIFFERENCE DATA SHEET

Model 4430 THRULINE® Wattmeter	36
Model 4431 THRULINE® Wattmeter	38
Series 4520 THRULINE® Wattmeter	42
Model 4305 THRULINE® Wattmeter	46
Model 4330/31 THRULINE® Wattmeter	47
Model 43P THRULINE® Wattmeter	50

ILLUSTRATIONS

Model 43 Outline Drawing	1
Installation Drawing, RF Line Section	4
Panel Cut for Mounting RF Body	4
Schematic Diagram - Element	8
Percent Reflected Power VS VSWR (1.0:1.3)	13
Percent Reflected Power VS VSWR (1.0:8.0)	14
Representative Frequency Response	18
VSWR Conversion Nomograph	23

TABLE OF CONTENTS [CONT.]

	Page
VSWR Conversion Nomograph	24
Cable Wavelength Matching Graph	26
Parts Illustration	32
Model 43P Inside View	52

TABLES

Specifications	ix
Element Tables	20
Replacement Parts List - Model 4430	38
Model 4431 - Coupling Data	40
Replacement Parts List - Model 4431	42
Replacement Parts List - Series 4520	44
Model 4305 Plug-In Element Table	46
Replacement Parts List - Model 4305	47
Model 4330/31 Plug-In Element Table	48
Replacement Parts List - Model 4330/31	49
Specifications for Model 43P	50

MODEL 43 THRULINE® WATTMETER

INTRODUCTION

PURPOSE AND FUNCTION

This instruction book covers the use and operation of the basic Model 43 THRULINE® Wattmeter. These instructions also apply to other units that are very similar to the Model 43 in electrical characteristics and operation.

These different models and their variations are also included in this book; however, the operational procedures and, in most cases, the electrical specifications of the Model 43 apply to these units as well. The basic difference in the majority of these units is physical, being panel rack mounted versions of the Model 43 THRULINE® Wattmeter. However, two of the units are similar in appearance but differ in as much as they have an RF sampler port included. The Model 43P has peak power handling capabilities.

All differences pertinent to these units can be found in the "Difference Data Sheets", in the back of this book.

The Model 43 THRULINE® Wattmeter is an insertion-type RF wattmeter, designed to measure power flow and load match in 50 ohm coaxial transmission lines. It is intended for use on CW, AM, FM, and TV modulation envelopes, but not pulsed modes. The Model 43, when used in 50 ohm applications, has an insertion VSWR of less than 1.05 to 1 up to a frequency of 1000 MHz. The meter is direct reading in watts, expanded down scale for easy reading and is graduated 25, 50, and 100 watts full scale. The power ranges used are determined by the Plug-In Elements, which fall in various frequency band groups covering from 0.45 to 2300 MHz plus additional special elements in various power and frequency ranges (see Section III - Operating Instructions). Further characteristics may be found on the Specifications page.

PERFORMANCE CHARACTERISTICS AND CAPABILITIES

The Model 43 THRULINE® Wattmeter is a portable unit contained in a die cast aluminum housing, with a formed metal enclosure on the back which is easily removed. Included with the unit is a leather carrying strap, four rubber shock feet on the base, and four rubber bumpers on the back, which allow the Model 43 to stand or lie flat when used. For additional protection, the microammeter is specially shock mounted. A slotted screw is provided on the lower front face of the meter for zeroing the pointer. Below the meter, the RF line section face protrudes slightly from the wattmeter housing with the Plug-In Element socket in the center.

A shielded cable connects the microammeter to the dc jack which is attached to the side of the RF line section casting. This cable, nearly three feet long, permits removal of the RF line section from the wattmeter housing. Meter connections may be maintained with any installations outside of the housing. This permits permanent additional installation to be made. See Section I - Installation.

Inside the dc jack assembly, there is a filter capacitor which shunts the meter circuit to prevent misreadings caused by stray RF energy existing in the Plug-In Element. Mounted on the dc jack is a phosphor bronze spring finger, which protrudes through a lateral hole and into the Plug-In Element socket of the RF line section.

The finger has a button on its end which mates with the contacts of the Plug-In Element. The silver plated brass RF line section is precision made to provide the best possible impedance match to the coaxial RF transmission line in which the Model 43 is inserted. The ends of the line section are nested in mating slots to provide additional mechanical support.

At each end of the line section are Bird Quick-Change type RF connectors, which may be quickly interchanged with any other Bird "QC" connector by removing the four screws on the mounting flanges. The wattmeter housing does not interfere with any connector changes.

To make measurements, the cylindrical shaped Plug-In Element is inserted into the line section socket and rotated against one of the two stops. A small catch in the upper right hand corner of the casting face presses on the shoulder of the Plug-In Element to keep it in proper alignment and assure a good contact with the dc jack and between the lower edge of the element and line section body. On diametrically opposite sides of the Plug-In Element body are contacts to provide dc pickup in either direction of power flow. These contacts make connection with the spring finger of the dc jack only when the Plug-In Element is in the precise forward or reverse position, which occurs only when the index pin on the element is in the lower level of the stepped line section casting face and against its respective stop.

The Model 43P THRULINE® Wattmeter has the same abilities as the Model 43 with the added feature of peak power measurement capabilities. A conversion kit (part number 4300-400) is available to convert any standard Bird Model 43 to peak reading capabilities. This kit comes complete with all necessary parts and easy to follow instructions for simple and quick conversion.

SPECIFICATIONS FOR MODEL 43 THRULINE® WATTMETER

This specification also includes data covering similar Models 43P, 4305, 4330, 4331, 4430, 4431, 4521, 4522, 4523, 4525, 4526, and 4527. Any specifications pertaining to a particular model will be found in the "Difference Data Sheets" located at the back of this book.

Impedance (All Models) 50 ohms nominal

Insertion VSWR

All Models except 4431	Less than 1.05:1 maximum
4431	Less than 1.07 when coupling is less than 30 dB

Connectors

RF Sampling	Female BNC
Primary Line	Bird "QC" Female N Normally supplied

Power and Frequency Range

Models 43, 43P, 4521/22/23/25/26	100 mW-10000 W full scale direct reading in watts, frequency range from 0.45 to 2300 MHz. Select elements from Tables 1, 2, 3, 4, and 6 found in Section III.
Models 4430 & 4527	1000 W maximum 2-200 MHz 500 W maximum from 200-512 MHz.

SPECIFICATIONS FOR MODEL 43
THRULINE® WATTMETER [CONT.]

Model 4431	5000 W maximum from 2-30 MHz 1000 W maximum from 30-1000 MHz (applicable only when coupling is less than 30 dB).
Model 4305	25 kW maximum from 0.45-2.5 MHz, 10 kW from 2-30 MHz.
Accuracy (All Models CW)	±5% of full scale.
(Model 43P, Peak Power)	±8% of full scale.
Dimensions	
Models 43 & 4430	3-5/8"L x 4"W x 6-7/8"H (92.1 x 101.6 x 174.6 mm)
Model 4431	3-27/32"L x 4"W x 6-7/8"H (97.6 x 101.6 x 174.6 mm)
Model 4305	4-5/32"L x 3-27/32" x 6-53/64" (105.6 x 98 x 173 mm)

SPECIFICATIONS FOR MODEL 43 THRULINE® WATTMETER [CONT.]

Weight

Model 43	3 lb (1.36 kg)
Model 43P	4 lb (1.8 kg)
Model 4430	3-1/4 lb (1.47 kg)
Model 4431	3-1/2 lb (1.59 kg)
Model 4305	3-1/4 lb (1.47 kg)

Operating Position Any

Finish (All Models) Light navy gray baked enamel

RF Coupling

Models 4430 & 4527	Approx. -53 dB from 512 MHz down to 10 MHz decreasing to -70 dB between 10 and 2 MHz.
Model 4431	Adjustable, 15-70 dB (See "Difference Data Sheet")

Insertion Loss (Model 4431)

2-512 MHz	0.1 dB maximum
512-1000 MHz	0.2 dB maximum*

*Above listed specifications are applicable only if maximum coupling used does not exceed 30 dB. This requires a minimum decoupling of four full turns counterclockwise (CCW) above 200 MHz and a minimum decoupling of seven full turns (CCW) above 800 MHz.

SECTION I - INSTALLATION

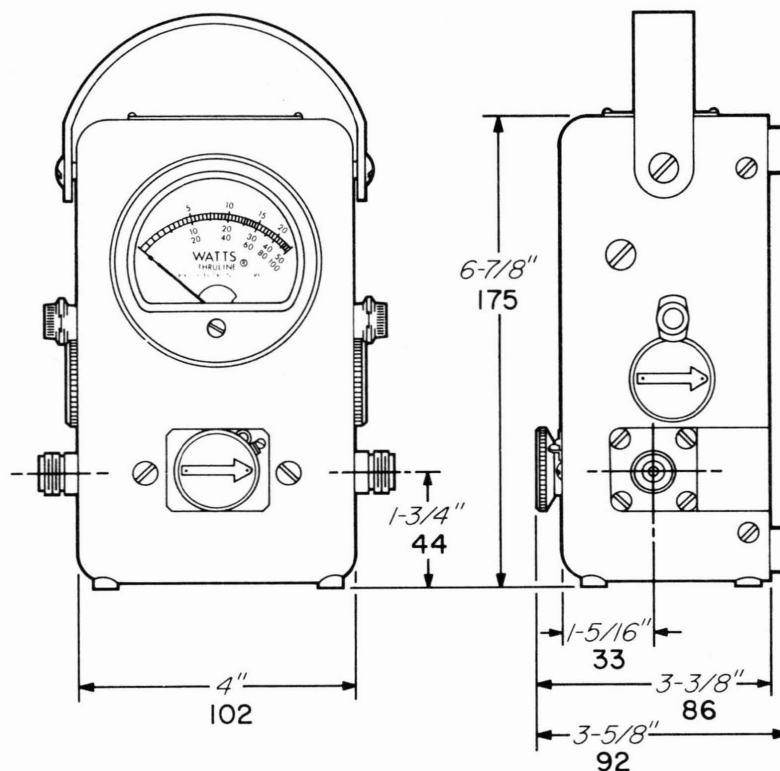
1-1. PORTABILITY

1-2. The Model 43 is a portable instrument, and the housing is not designed for fixed mounting (see figure 1-1). A strap is provided for carrying purposes.

CAUTION

Do not drop the THRULINE® Wattmeter or its elements or subject them to hard blows. The microammeter is shock mounted in the wattmeter housing, but its delicate mechanism may be damaged by severe impact.

FIGURE 1-1. MODEL 43 OUTLINE DRAWING



1-3. While transporting the THRULINE® Wattmeter, it is best to reinsert the original dust plug, or a Plug-In Element with the arrow pointed upward, in the measuring socket, and secure with the catch. This will shunt the meter circuit and serve to protect the meter by dampening needle action during handling or shipping. Also, secure spare Plug-In Elements in their receptacles with the pivoting knob clamps; just insert the element to seat and twist knob one-quarter turn to hold. Handle the Plug-In Elements with care at all times. Calibration could be disturbed if they are dropped.

1-4. CONNECTIONS

1-5. Insert the Model 43 Wattmeter in coaxial transmission lines of 50 ohms nominal impedance. It is indifferent to which respective side the power source and the load connections are made. If cables other than 50 ohm type are used, a mismatch will occur causing probable serious inaccuracies in readings. However, if a mismatch cannot be avoided, the results may be calculated per para 3-33, Impedance Mismatch. We strongly urge that you avoid this condition.

1-6. The Model 43 is normally supplied with two Female N type connectors which are of the Bird Quick-Change design. Other "QC" connectors are available as listed:

Male N	Female BNC
Female HN	Male BNC
Male HN	Female LC
Female C	Male LC
Male C	Female LT
Female UHF	Male LT
Male UHF	Female TNC
7/8" EIA Air Line	Male TNC

1-7. These may be purchased from Bird Electronic Corporation as required. See Section V - Replacement Parts List.

1-8. The above connectors are quickly changed by removing the four 8-32 pan head machine screws from the corners of the connector flange, and pulling

straight out. Reverse this procedure to attach connector, making sure the center contact pin aligns properly with the socket.

1-9. REMOTE INSTALLATION

1-10. The RF line section can be removed from the meter housing for remote installation. To remove the line section from its housing:

- a. Unscrew the four 8-32 flat head machine screws holding the back cover.
- b. Grasp the cover by the side filler tabs and pull directly backwards. The back cover assembly will come off with the speed nuts remaining attached.
- c. Remove the two 10-32 oval head machine screws on the front of the housing.
- d. Slide the line section backwards out of the housing. Do not loosen the two oval head screws on the sides of the housing in line with the meter. These hold the meter supporting shock ring in place.
- e. Substitute the cable which attaches the line section to the meter with a sufficient length of cable to make the remote installation.
- f. To replace the RF line section, reverse the above listed procedures.

1-11. It may be desirable to have two or more line sections permanently installed in continuous operating equipment. In this case, one set of elements and one meter may be used to measure several RF transmission lines without interruption of RF lines for insertion of the THRULINE® Wattmeter. Additional RF line sections are available (see figure 1-2).

FIGURE 1-2. INSTALLATION DRAWING, RF LINE SECTION

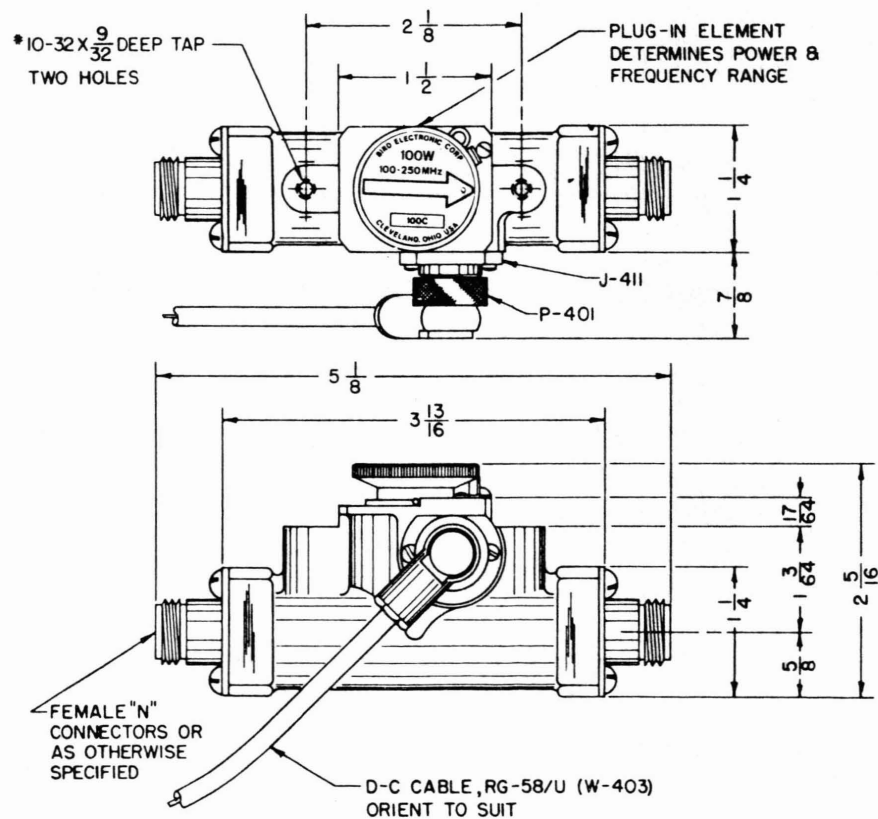
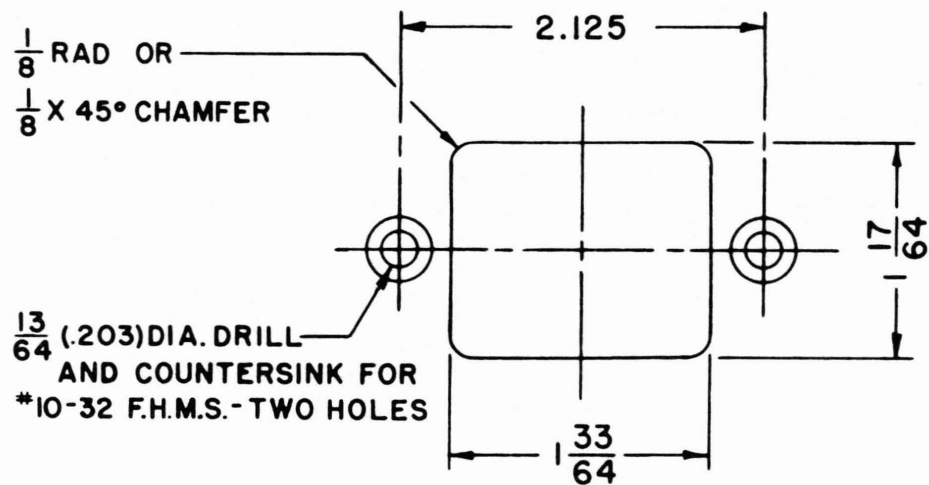


FIGURE 1-3. PANEL CUT FOR MOUNTING RF BODY



1-12. The RF line section of the Model 43 lends itself very readily to panel type mounting. A layout for the panel mount cut is given in figure 1-3. The thickness of the panel should be about 1/4 inch. On panels less than this, build up the thickness with pads or washers to achieve a flush-face mounting. Cable connections are simplified because the RF line section may be mounted in any convenient direction. Attach the line section so that the finger catch is in the most accessible position.

SECTION II - THEORY OF OPERATION

2-1. TRAVELLING WAVE VIEWPOINT

2-2. The best way to visualize the THRULINE® Wattmeter principle is from the Travelling Wave viewpoint. In transmission lines, the voltages, currents, standing waves, etc., on any uniform line section are the result of the interaction of two travelling waves:

- a. The forward wave travels (and its power flows) from the source to the load. It has RF Voltage E_f and current I_f in phase, with $E_f / I_f = Z_o$.
- b. The reflected wave originates by reflection at the load, travels (and its power flows) from the load back to the source, and also has an RF voltage E_r and current I_r in phase, with $E_r / I_r = Z_o$.
- c. Note that each component wave is mathematically simple, and is completely described by a single figure for power, for instance:

$$W_f = \text{Watts Forward} = E_f^2 / Z_o = I_f^2 Z_o = E_f I_f$$

$$W_r = \text{Watts Reflected} = E_r^2 / Z_o = I_r^2 Z_o = E_r I_r$$

2-3. Z_o is the characteristic impedance of the uniform line, and simplifies matters by being nearly a pure resistance, usually 50 ohms, for useful lines. The main RF circuit of the Model 43 is a short piece of uniform air type line section, whose Z_o is 50 ohms, in which accurate measurements may be made.

2-4. COUPLING CIRCUIT

2-5. The coupling circuit which samples the travelling waves is in the Plug-In Element. The circuitry of the element and its relationship to the other components of the Model 43 are illustrated in the schematic diagram, figure 2-1. Energy will be produced in the coupling circuit of the element by both mutual inductance and capacitance from the travelling RF waves in the line section. The inductive

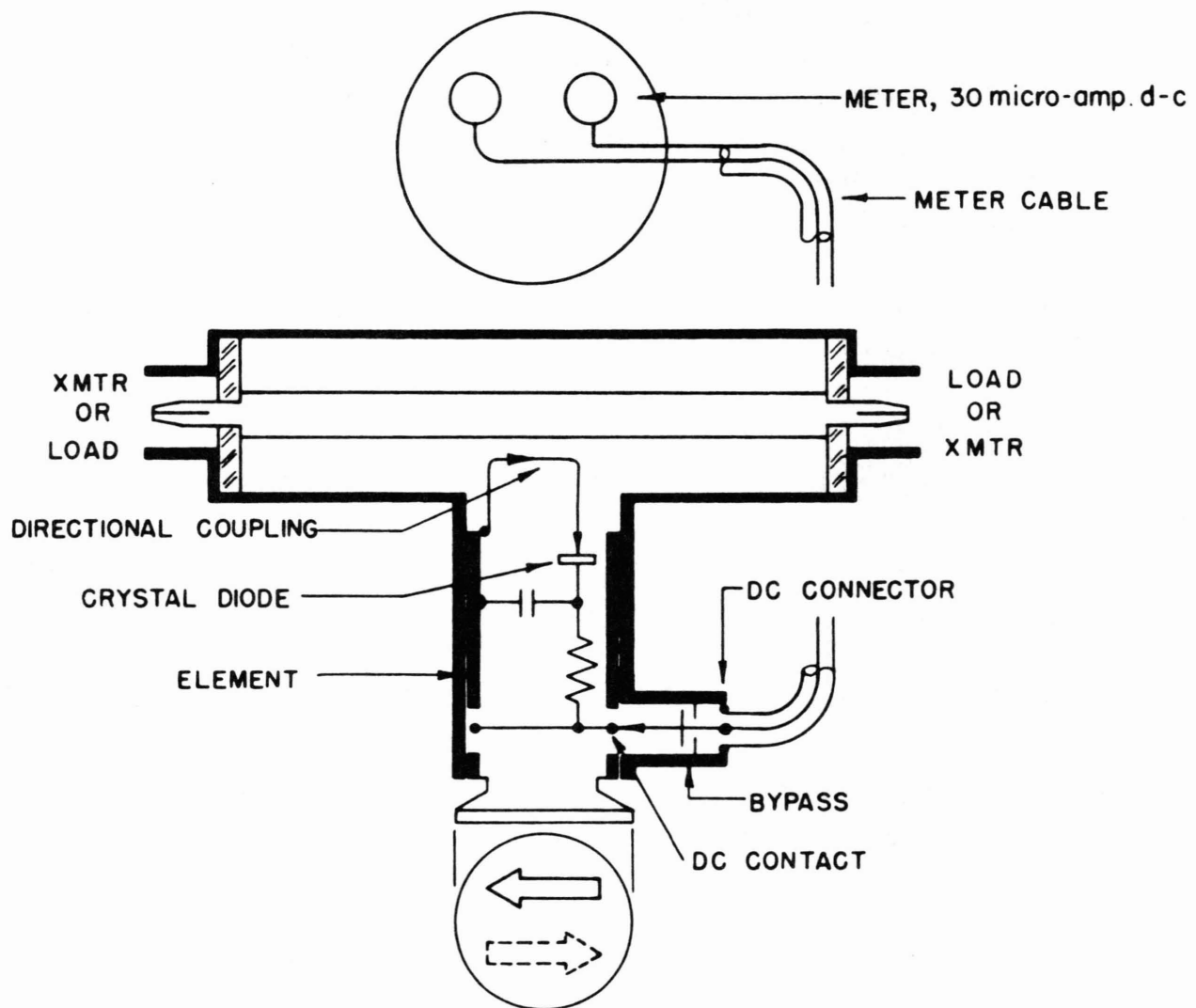
currents will flow according to the direction of the travelling waves producing them. The capacitive portion of these currents is independent of the direction of the travelling waves. Therefore, assuming that the Plug-In Element remains stationary, it is apparent that the coupling currents produced from the waves of one direction will add in phase, while those produced from the waves of the opposite direction will subtract in phase. The additive or ARROW direction is assigned to the forward wave.

2-6. The electrical values of the element circuits are carefully balanced and so designed that the inductive current produced from the reverse wave will cancel its portion of the capacitive current almost completely. The result is a directivity always higher than 25 dB, which means that the element is highly insensitive (nulled) to the reverse direction wave. By being highly directional, the element is sensitive at either one of its settings, but to only one of the two travelling waves which produce standing waves by interference. THRULINE® Wattmeter measurements are also independent of their position along the standing waves.

2-7. STANDING WAVE RATIO VS REFLECTED/FORWARD POWER RATIO

2-8. As mentioned above, the THRULINE® Wattmeter technique uses the Travelling Wave viewpoint to measure most of the outstanding facts about transmission line operation. Another widely used and related viewpoint, is the Standing Wave one, which is quite elaborately developed both mathematically and in existing equipment. This technique can be traced to the early development of slotted lines as tools of exploration.

FIGURE 2-1. SCHEMATIC DIAGRAM - ELEMENT



2-9. The slotted line is a standing wave instrument and emphasizes this viewpoint. However, the slotted line is too long, too expensive if good, not portable, and slow in operation. These objections increase rapidly as the frequency drops below 1000 MHz. Whereas the THRULINE® Wattmeter is surprisingly quick, convenient, and accurate by comparison. With the exception of phase angle reflection (distance, load to minimum), it tells everything a slotted line will.

2-10. The relationship between the Travelling Wave and the Standing Wave viewpoints is given in most high frequency textbooks.

SECTION III - OPERATION INSTRUCTIONS

WARNING

When operating this equipment in conjunction with RF power of 200 watts or higher, the potential of the center conductor of the RF line section will be 100 volts or higher. Do not contact the center conductor. If cleaning becomes necessary, shut off the RF power.

3-1. GENERAL

3-2. The apparent features of the Model 43 equipment have been discussed in the Introduction, Theory of Operation, and in the Installation Sections. Measurements are made by the insertion and operation of the Plug-In Elements previously mentioned.

3-3. The elements determine the power range to be read on the meter scale, and the major markings (viz. 50W, 100W, etc.) are the full scale power value for the element. Elements are also marked for frequency range. The transmitter frequency must be within the band of the element used. Elements are available as listed in table 3-1 on pages 20 through 22.

3-4. See para 3-28 (Frequency Response) of this section for frequency band flatness and performance of the elements outside of their stated frequencies. Elements for additional ranges (power or frequency) may be ordered without returning the Model 43 for calibration, since the RF bodies and meters are standardized, and are designed for a wide range of coaxial transmission power value and frequencies.

3-5. The ARROW on Plug-In Elements indicate sensitive direction; i.e., the direction of power flow which the meter will read. "Arrow" and "Reverse" are directional terms used in reference to the THRULINE® Wattmeter Element, and mean respectively the sensitive and insensitive directions of the element. Rotate the element to reverse the sensitive direction. "Forward" and "Reflected" are

directional terms used in reference to the source-load circuit. Note that the transmitter may attach to either connector of the wattmeter. It makes no difference which external RF connection is selected, since the elements are reversible and the RF circuit is symmetrical end for end. Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions.

3-6. The THRULINE® Wattmeter used with a TERMALINE® Load Resistor of proper power rating forms a highly useful absorption wattmeter. With the ARROW set toward the load, it is unnecessary to reverse the element, because the reflected power should be negligible.

3-7. In cases where readings are being made when the meter unit is connected to an auxiliary RF line section, always remove any measuring element from the unused RF line section. Otherwise, the dc circuit will be unbalanced or shorted according to the arrow position of the other element, causing inaccurate or no indication on the meter.

3-8. **LOAD POWER**

3-9. Power delivered to and dissipated in a load is given by:

$$W_l = \text{Watts into Load} = W_f - W_r$$

Where appreciable power is reflected, as with an antenna, it is necessary to subtract the reflected power from the forward power to get the actual load power. This correction is negligible (less than 1 percent) if the load is such as to have a VSWR of 1.2 or less. Good load resistors, such as Bird TERMALINE® loads, will thus show negligible or unreadable reflected power.

3-10. VSWR scales and their attendant controls for setting the reference point have been intentionally omitted from the Model 43 for two reasons.

- a. Why make something similar to a hypothetical dc volt-ohm-meter with control pots for the voltmeter multipliers? Even more complications arise when diodes at RF are involved.

- b. Experience using the THRULINE® Wattmeter for transmitter tune-up, antenna matching, etc. (i.e., on operating problems), shows that the power ratio ϕ is as useful in practice as the standing wave ratio $p = \text{VSWR}$.

3-11. A trial is suggested for a few days - forget VSWR and try thinking in terms of $\phi = W_r / W_f$ when the THRULINE® Wattmeter is used. It will be noted that even without bothering to calculate the ratio exactly, the two meter readings W_r and W_f give an automatic mental impression which pictures the situation. Thus, for an antenna matching problem, the main objective usually is to minimize W_r . Anything done experimentally to this end is noted directly when the Model 43 element is turned to the reflected position. Furthermore, the ratio of readings, even if only mentally evaluated, is a reliable guide to the significance of the remaining reflected power.

3-12. p VS ϕ AND ITS SIGNIFICANCE

3-13. Since there are definite simple relationships:

$$p = \frac{1 + \sqrt{\phi}}{1 - \sqrt{\phi}} \text{ and } \phi = \left[\frac{p - 1}{p + 1} \right]^2 \quad \text{where } p = \text{VSWR} \quad \text{and } \phi = \frac{W_r}{W_f}$$

between standing wave ratio p and the reflected/forward power ratio ϕ , indicated by the THRULINE® Wattmeter, the latter may be conveniently used to measure VSWR. The relationship is given in figures 3-1 and 3-2.

3-14. Note that when $\phi = 10$ percent, below which W_r will appear insignificant and may be hard to read, you are close to the commonly accepted lower limit $p = 2$, below which improved antenna match becomes less and less worthwhile in many systems. Experimentally, by using the THRULINE® Wattmeter, it can be readily shown that reducing ϕ below 10 percent produces little gain in the way of increased W_f . TV transmitter antenna lines, and VHF omnirange transmitters are

among those systems that require much lower levels of reflected power but for reasons other than simple power transmission. Note that in figure 3-1, the very small level of reflected power, i.e., $\phi = 0.06$ percent corresponds to $p = 1.05$. While both forward and reflected power levels can be measured with the same element, detection of reflected power is possible down to about $\phi = 1$ percent ($p = 1.2$), provided W_f approaches full scale. However actual measurement is possible only down to about $\phi = 5$ percent ($p = 1.5$). For more accurate measurements of reflected power levels, an element rated at one tenth of the full scale power value of the element used to measure forward power is recommended.

FIGURE 3-1. PERCENT REFLECTED POWER VS VSWR (1.0:1.3)

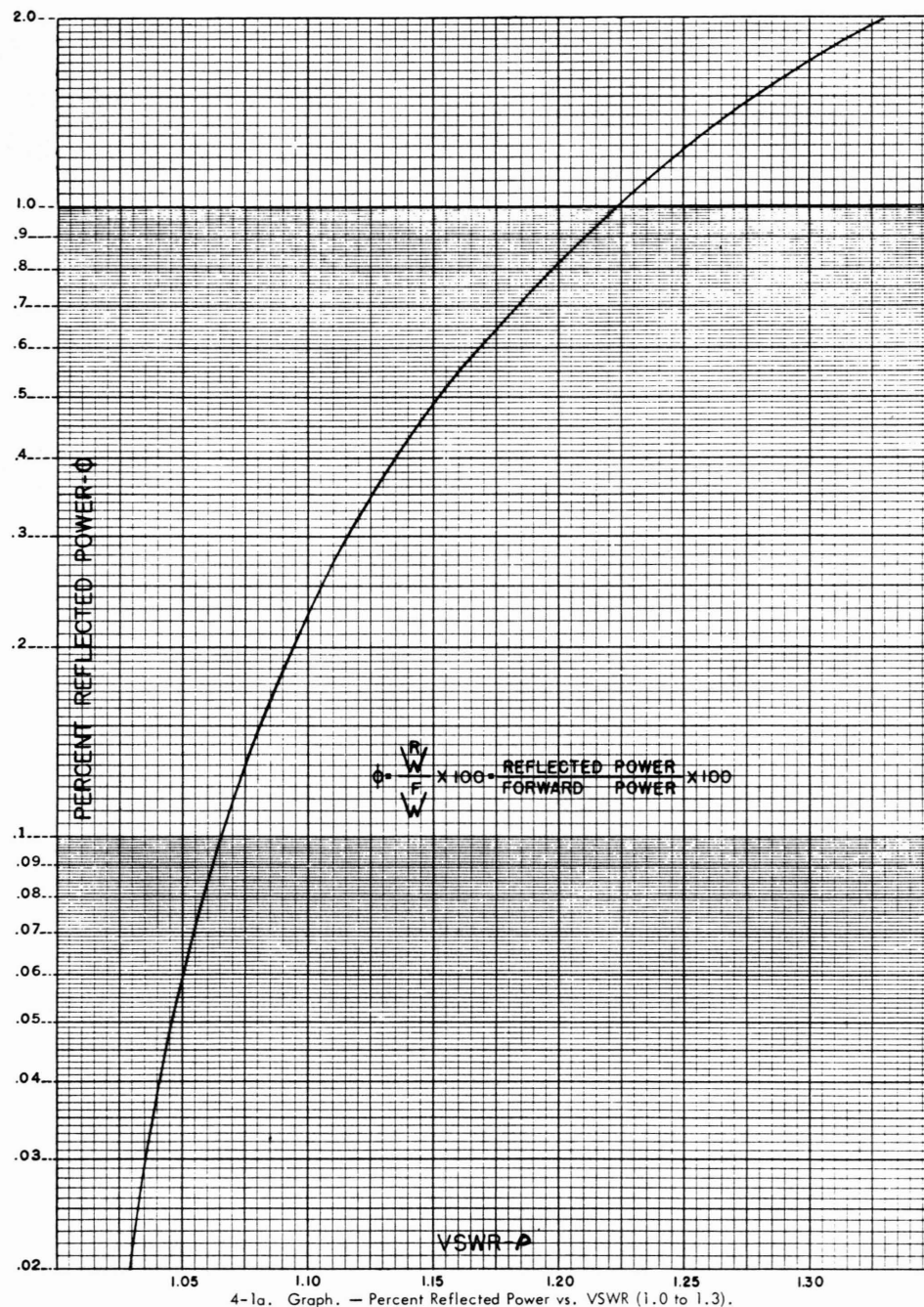
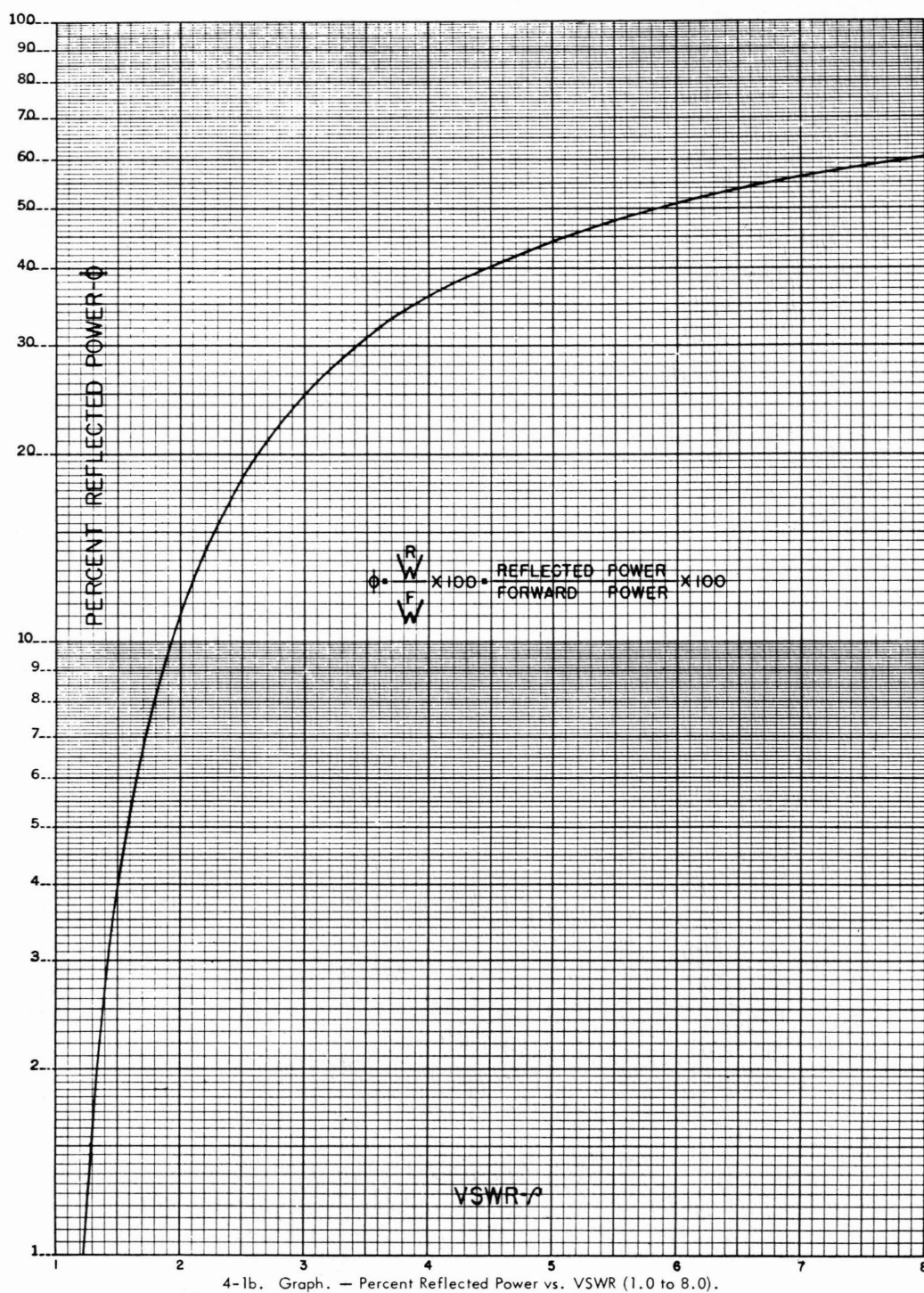


FIGURE 3-2. PERCENT REFLECTED POWER VS VSWR (1.0:8.0)



CAUTION

When making low reflection readings using a more sensitive element, take care to insert the element so that it senses reflected power only. Do not rotate the element in the socket so that it is subjected to forward power. This can result in damage to the Plug-In Element, the microammeter, or both.

3-15. Low reflection measurements may be extended below this with two elements. Say 80 watts are available, and you have 100 watt and ten watt elements.

3-16. Measure W_f with the 100 watt element. Remove the 100 watt element and insert the ten watt element. The ten watt element must be inserted only in the reflected direction, ARROW toward transmitter. Insert and remove only this way. Now read W_r on the ten watt element.

3-17. In this case, measurement down to at least 0.5 watt reflected is possible, which means to say:

$$\phi = \frac{0.5}{80} \text{ or close to } 0.6\% \text{ or to roughly } p = 1.16$$

and detection of reflected power is possible down to about 0.1 watt.

$$\phi = \frac{0.1}{80} = 0.00125 \text{ or close to } 0.1\% \text{ or to roughly } p = 1.06$$

3-18. Caution is necessary in the above method and preferably it should not be used with element ranges differing by more than 10 to 1 although 25 to 1 can be used with extreme caution. With elements now available having ranges down to one watt or less full scale, this method is usable with medium and low power transmitters.

3-19. MEASUREMENT AND MONITORING OF TRANSMITTER POWER

3-20. Little more need be said about this in view of the preceding discussion. The THRULINE® Wattmeter is useful for the continuous monitoring of transmitter output and is also helpful for the continuous monitoring of reflected power, for instance in checking intermittent antenna or line faults.

3-21. Like diode devices in general, the Model 43 indicates the carrier component on amplitude modulation, with very little response to side band components added by modulation.

3-22. TESTING OF LINES, CONNECTORS, FILTERS, ETC.

3-23. The THRULINE® Wattmeter is highly useful for this purpose, and may be employed in several ways.

a. VSWR (Insertion) or ϕ (Insertion) may be measured with the line terminated in a good TERMALINE® Load Resistor. The lower limits of sensitivity in this are given above in para 3-14 through 3-19.

b. ATTENUATION (power lost by heat in the line) as well as VSWR (Insertion) and ϕ (Insertion) may be measured by inserting the unknown line between THRULINE® Wattmeter units, or between two RF line sections using only one meter and one set of elements (the end of the line to be terminated in a good load resistor). This method applies also to insertion between a THRULINE® Wattmeter and a TERMALINE® Absorption Wattmeter. Very small values of attenuation require allowance for normal instrument errors. The correction may be determined by direct rigid connection of the THRULINE® Wattmeter units, or of the THRULINE® Wattmeter - TERMALINE® Load combination, in cascade. Slight juggling of zero settings is permissible for convenience in eliminating computation, provided readings are being taken fairly well up on scale.

c. ATTENUATION BY OPEN OR SHORT CIRCUIT METHOD. More clever by far than method (b) is one depending on the high directivity (null balance) to which the THRULINE® Wattmeter elements are held. They should, and do, exhibit good equality between forward and reflected readings when the load connector is open or short circuited. In this condition, $\phi = 100$ percent, the forward and reflected waves being equal in magnitude, and $p = \text{infinity}$. Say that this is checked on open circuit, and then a length of line of unknown attenuation, also open circuited, is connected to the load connector. The ratio ϕ then shown is the attenuation in two passes along the line (down and back).

3-24. Expressed in dB,

$$\left(\text{using the equation } N_{dB} = 10 \log \frac{W_f}{W_r} \right),$$

the dB figure may be compared with published data for line type and length by remembering to halve N_{dB} or to double the line length, because twice the line length is actually being measured.

3-25. This measurement should be supplemented by one of ϕ (Insertion) as in para 3-23 above, or at least by dc continuity and leakage checks, since the attenuation measurement alone can be in error from faults such as open or short circuits part of the way down the line.

3-26. Open circuit testing is somewhat to be preferred to short circuit, since the reference short (used to check equality initially) must be good, and because the initial equality is somewhat better on open than on short circuit.

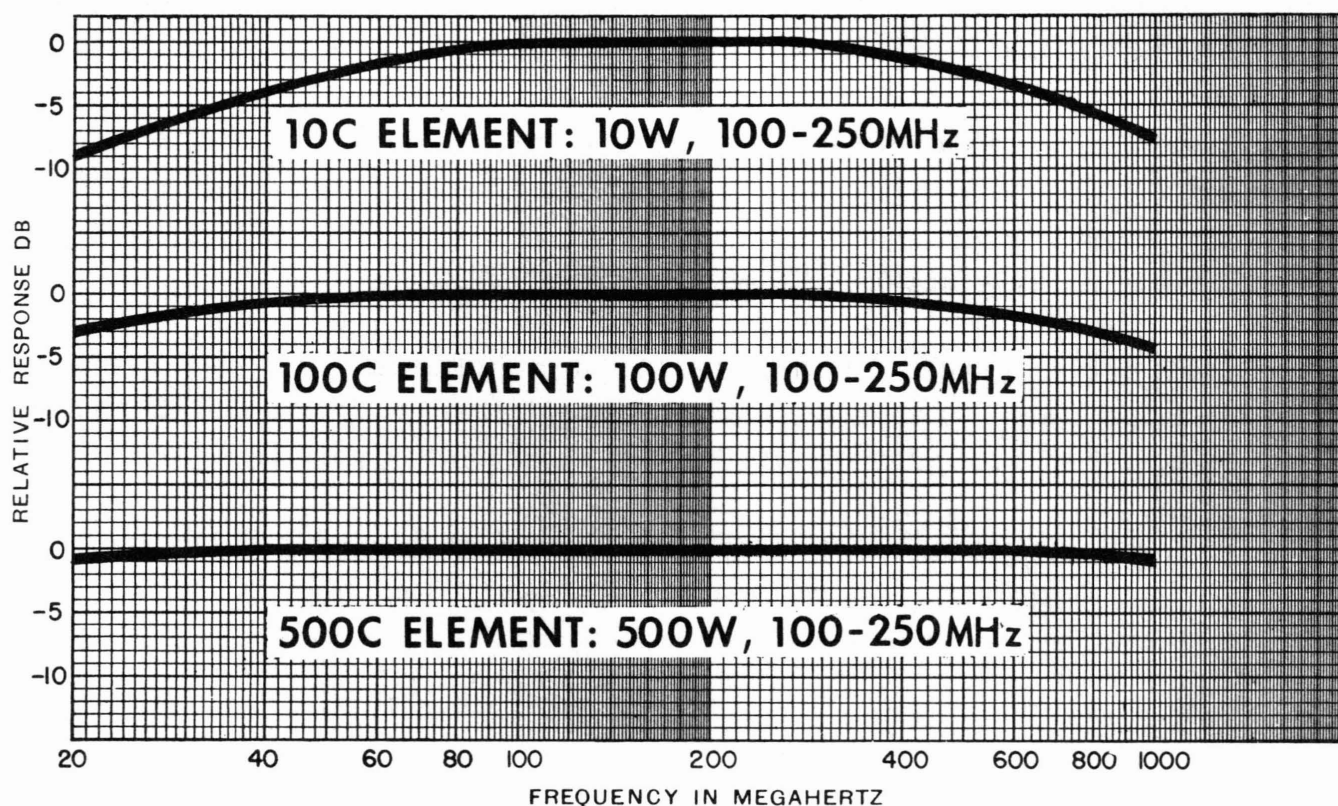
3-27. Again, for quite low values of attenuation, it is advisable to note exact readings, or difference, on the initial equality check, and to allow for this difference.

3-28. FREQUENCY RESPONSE

3-29. The Plug-In Elements have a very flat frequency response over a frequency ratio of more than 2-1/2 to 1. This characteristic provides a practically flat response within the assigned frequency ranges for all the elements (see Table 3-1).

3-30. An illustrative set of curves for three elements of one of these frequency bands is shown in figure 3-3. Notice that on the low power element, the fall-off above and below the assigned frequency band is more pronounced than it is for the high power element. The degree of drop in response varies progressively less for each power level from low to high. For example, at 40 MHz, the 10C element will typically read about 4 dB low which is about 40 percent of the true value or 4 watts. The 100C will read only about 1 dB low or about 80 percent of the true value (80 W) and the 500C should read within the normal 5 percent of full scale tolerance. These curves, figure 3-3, may be assumed to be about typical for all of the listed band types (H, A, B, C, D, etc.) at their respective stated frequencies.

FIGURE 3-3. REPRESENTATIVE FREQUENCY RESPONSE



3-31. Harmonics, or subharmonics, may be known to exist in the measured circuit, outside of the element frequency band. If so, a rough approximation of the response of the element to these harmonics may be made by the use of these curves. The frequency ordinate to be read on the graph will be obtained by proportioning the frequency of the element used with that of the one illustrated. Interpolation of the curve values will give an approximation of the extent to which these harmonic signals are being measured by your element.

3-32. Nevertheless, the use of an element for direct power measurements outside of its stated frequency range is not recommended. The responses given are only typical, and are by no means guaranteed (see para 3-30).

3-33. IMPEDANCE MISMATCH

3-34. There may be cases where it is necessary to use the Model 43 on other than the 50 ohm circuit for which it is designed.

3-35. When using the THRULINE® Wattmeter, you will be inserting a four-inch length of 50 ohm air line into the circuit and therefore the load on the transmitter will be changed from its original condition without the THRULINE® Wattmeter. If the reflected power is less than 10 percent and the frequency is below 200 MHz, the four-inch length will produce a mismatch that is not too serious. But going any higher than these values, even if the transmitter is tuned up with the Model 43 in place, the load impedance will be very different after the THRULINE® Wattmeter is removed.

3-36. The Model 43 in a 50 ohm line will indicate zero reflection when the load, at its load connector, is 50 ohms, pure resistive. However, even an ideal condition on a 70 ohm line on the load side of the wattmeter will show 3 percent reflected power and cause a VSWR of 1.4 to 1.0. (If THRULINE® Wattmeter is 50 ohms and load is 70 ohms resistive, VSWR in the wattmeter is $70/50 = 1.4$.) The THRULINE® Wattmeter could also show this same reflected percentage with a $50/1.4 = 35.7$ ohms pure resistive load which could exist with 10 percent reflected

power on the 70 ohm line (VSWR = 2). From this you can see that the 70 ohm line could actually have as much as 10 percent reflected power and a VSWR = 2 even though the THRULINE® Wattmeter indicates only 3 percent reflected power, and a VSWR = 1.4.

3-37. It should be especially remembered that with 70 ohm lines it is most important to measure the reflected power and subtract it from the forward, because of this factor being so much more critical here than with a 50 ohm line.

TABLE 3-1. ELEMENT TABLES

Table 1 - Standard Elements

Power Range	Frequency Bands (MHz)					
	2-30	25-60	50-125	100-250	200-500	400-1000
5 W		5A	5B	5C	5D	5E
10 W		10A	10B	10C	10D	10E
25 W		25A	25B	25C	25D	25E
50 W	50H	50A	50B	50C	50D	50E
100 W	100H	100A	100B	100C	100D	100E
250 W	250H	250A	250B	250C	250D	250E
500 W	500H	500A	500B	500C	500D	500E
1000 W	1000H	1000A	1000B	1000C	1000D	1000E
2500 W	2500H					
5000 W	5000H					

Table 2 - Low Power Elements

1 Watt	Cat. No.	2.5 Watts	Cat. No.
25-30 MHz	025-1	30-40 MHz	030-2
30-35 MHz	030-1	40-50 MHz	040-2
35-40 MHz	035-1	50-60 MHz	050-2
40-50 MHz	040-1	60-80 MHz	060-2
50-60 MHz	050-1	80-95 MHz	080-2
60-80 MHz	060-1	95-150 MHz	095-2
80-95 MHz	080-1	150-250 MHz	150-2
95-125 MHz	095-1	200-300 MHz	200-2
110-160 MHz	110-1	250-450 MHz	250-2
150-250 MHz	150-1	400-850 MHz	400-2
200-300 MHz	200-1	800-950 MHz	800-2
275-450 MHz	275-1		
425-850 MHz	425-1		
800-950 MHz	800-1		

Table 3 - High Frequency Elements

Power Range	Frequency Bands (MHz)			
	950-1260	1100-1800	1700-2200	2200-2300
1 W	1J	1K	1L	1M
2.5 W	2.5J	2.5K	2.5L	2.5M
5 W	5J	5K	5L	5M
10 W	10J	10K	10L	10M
25 W	25J	25K	25L	25M
50 W	50J			
100 W	100J			
250 W	250J			

Table 4 - Low Frequency Elements

Power Range	Frequency Band .45 to 2.5 MHz
1000 W	1000P
2500 W	2500P
5000 W	5000P
10000 W	10000P

Table 6 - Milliwatt Elements

100 mW	Cat. No.	250 mW	Cat. No.	500 mW	Cat. No.
72-76 MHz	430-2	70 MHz	430-34	72-76 MHz	430-33
105-120 MHz	430-6	72-76 MHz	430-22	105-120 MHz	430-26
125-136 MHz	430-9	108-118 MHz	430-24	240-290 MHz	430-27
160-175 MHz	430-10	130-150 MHz	430-13	328-336 MHz	430-28
328-336 MHz	430-3	150-180 MHz	430-15	455-470 MHz	430-30
400-420 MHz	430-7	328-336 MHz	430-16	800-900 MHz	430-109
450-470 MHz	430-8	800-900 MHz	430-108		
800-900 MHz	430-107	1700-1750 MHz	430-17		

Special elements are also available; consult the factory.

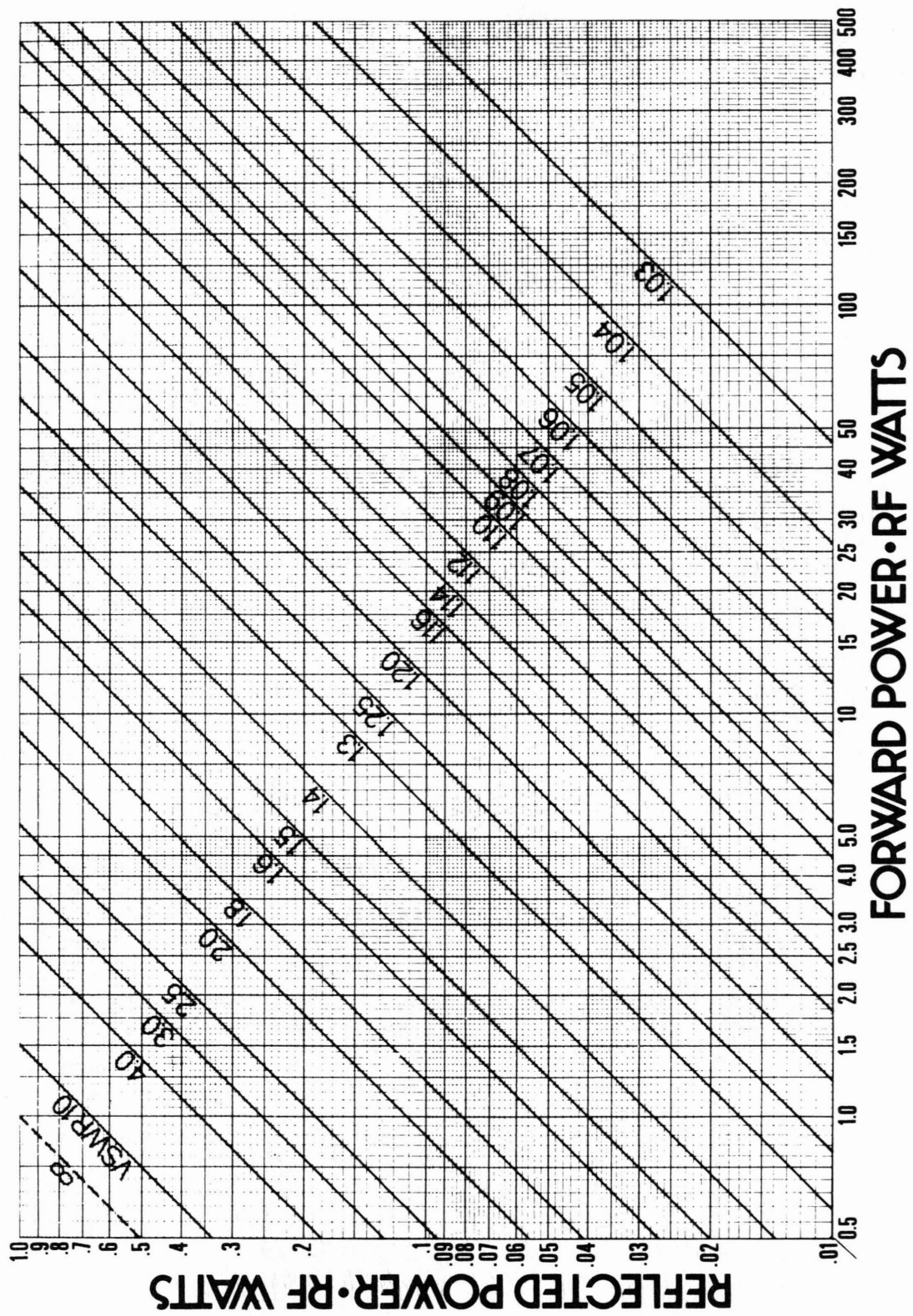
3-38. For the convenience of users, a set of VSWR conversion nomographs is included in this instruction book. With these charts, VSWR may be directly ascertained from forward and reflected power values read from the THRULINE® Wattmeter.

3-39. When a Model 43 is used to match a load to a transmitter and a good match is obtained, removing the instrument will not cause any change in the conditions, since a good 50 ohm load can be placed at the end of a 50 ohm transmission line of any length without altering conditions at the transmitter.

Using the VSWR Nomograph, determine the intersection of the forward and reflected power values. The slanted line passing closest to this point indicates the VSWR.



FIGURE 3-5. VSWR CONVERSION NOMOGRAPH

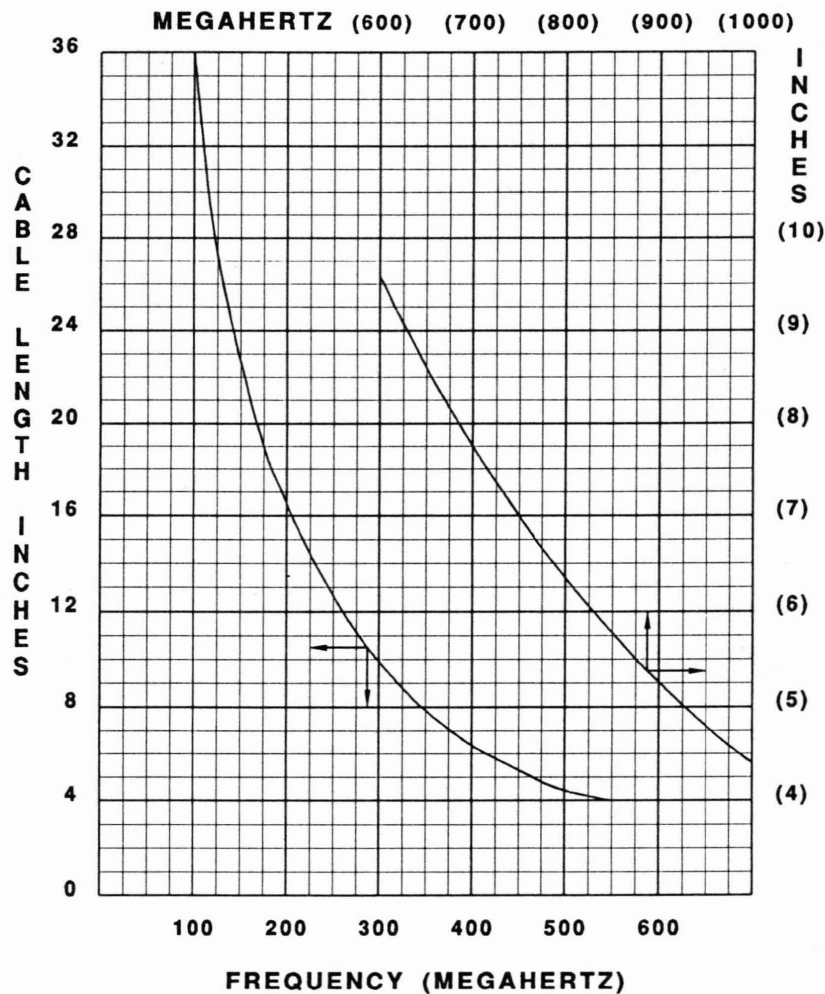


3-40. What happens when the load is not well matched, like an antenna with a VSWR of 1.5 or 2.0? Since the length of line between a mismatched load and the source transforms the impedance of the load as seen at the source, line length now becomes critical. If the adjustments for maximum power transfer were made with the Model 43 in place, removing it shortens the line by four inches, plus two connectors. This still is no cause for concern at low frequencies where four to five inches is a small fraction of a wavelength. At higher frequencies; e.g., above 100 MHz, power output and frequency of the source may be affected.

3-41. It is a principle of transmission line theory that the impedance is identical on either side of a $1/2$ wavelength. In order to duplicate the conditions in your transmission line with the Model 43 either in or out of the line, it is only necessary to insert or remove a $1/2$ wavelength.

3-42. This is easily done by making up a length of cable which, when added to the THRULINE® Wattmeter, equals $1/2$ wavelength at the frequency of measurement. If more than one frequency is involved, a separate cable is needed for each frequency.

FIGURE 3-6. CABLE WAVELENGTH MATCHING GRAPH



NOTES:

1. Physical cable length shown in inches is measured from end to end of outer conductor of connectors (TNC and N Male connectors), except for cables with UHF or Mini-UHF plugs where the cable length is measured from tip to tip of the center pins.
2. Dimensions shown are for SOLID polyethylene cable (e.g. RG-58C/U, RG-8/U) which has 66% the velocity of propagation relative to air. If so-called "RG-58 type" or "RG-8 type" cables (which often contain foam polyethylene) are used, the dimensions in the graph must be multiplied by that cable's relative velocity (say 79%) divided by 66% (i.e. by a factor of $79\% \div 66\% = 1.2$).

SECTION IV - MAINTENANCE

4-1. GENERAL

4-2. With the simple construction and generally self-contained nature of the Model 43 equipment, there is only a moderate amount of maintenance required. One of the major precautions is in handling; use reasonable care and do not drop the THRULINE® Wattmeter equipment or the Plug-In Elements.

4-3. CLEANING

WARNING

When using dry cleaning solvents, provide adequate ventilation and observe normal safety precautions. Many dry cleaning agents emit toxic fumes that could be harmful to your health, if inhaled.

4-4. The main factor in maintenance is care and cleanliness. The element socket should be kept plugged as much as possible to prevent the intrusion of dust. When a Plug-In Element is used for this purpose, use highest power element available. It should be positioned with the ARROW pointing upwards. This protects the meter and will not expose the element crystal to dangerous potentials if the RF line section should be energized. If any of the contacts or line connectors become dirty, they should be cleaned with a good contact cleaner or dry cleaning solvent on a cotton swab stick. Avoid excessive skin contact or inhalation of fumes when using. Exercise special care if carbon tetrachloride is used. Clean all contact areas and especially the exposed faces of the Teflon insulators.

4-5. It is particularly important to keep the mating surfaces of the socket and Plug-In Element clean. This applies to the bore of the socket and the circumference of the Model 43 element body, but most importantly to the bottom rim of the element body and the seat at the base of the socket in the line section. Also, check the ends of insulated dc contacts on the Model 43 element to see that they are clean and smooth. These parts should be carefully cleaned with a cotton swab stick and dry cleaning solvent. There must be a good contact between the base of the Plug-In Element and its socket to assure stable operation of the THRULINE® Wattmeter.

4-6. CONTACT ADJUSTMENT

4-7. In cleaning the socket bore, the operator should be careful not to disturb the spring finger of the dc contact. It is important that the operating position of this part be properly maintained. If the spring finger of the dc contact requires adjustment, it may be done manually if carried out with care. The button must be positioned far enough out to maintain good contact with the element, but not so far as to interfere with easy entry of the element body. The dc jack, with spring finger, may be removed for access by unscrewing the two 4-40 fillister head machine screws which fasten it to the side of the RF line section. Then retract its assembly, watching carefully so as not to lose the small Teflon positioning bead that straddles the base of the phosphor bronze spring and nests in a counterbore on the side of the RF body. When replacing the assembly, be sure that the bead is again properly inserted.

4-8. If there is any evidence of contamination inside the RF line section, the reachable portions should be likewise wiped and the interior carefully blown out. Under no circumstances attempt to remove the RF center conductor. It is tightly frozen in place and any attempt to remove it will ruin the assembly. Keep all connections tight, and keep the nut of the meter cord plug turned tight on the line section dc jack. This connection may often be serviced by simply loosening the nut of the dc plug, swinging the body several times through a fraction of a turn, and retightening the knurled nut securely.

4-9. TROUBLESHOOTING

4-10. As a brief guide to the operator in isolating occasional difficulties that may occur in the use of the Model 43, the following summary is included. The remedies for same are referenced to the text in this section or are self-evident.

PROBLEM	POSSIBLE CAUSE	REMEDY
No meter indication	No RF power	Check RF source.
	ARROW on Plug-In Element pointing in wrong direction.	Reposition element.
	No pick-up from dc contact finger	Adjust per para 4-6, Contact Adjustment.
	Open or short circuit in dc meter	Replace defective cable (RG-58/U).
Intermittent or inconsistent meter readings	Meter burned out or damaged	Replace or return wattmeter to the factory for meter replacement and recalibration.
	Faulty transmission line or antenna	Inspect line.
	Dirty dc contact on elements	Clean per para 4-3, Cleaning.

TROUBLESHOOTING [CONT.]

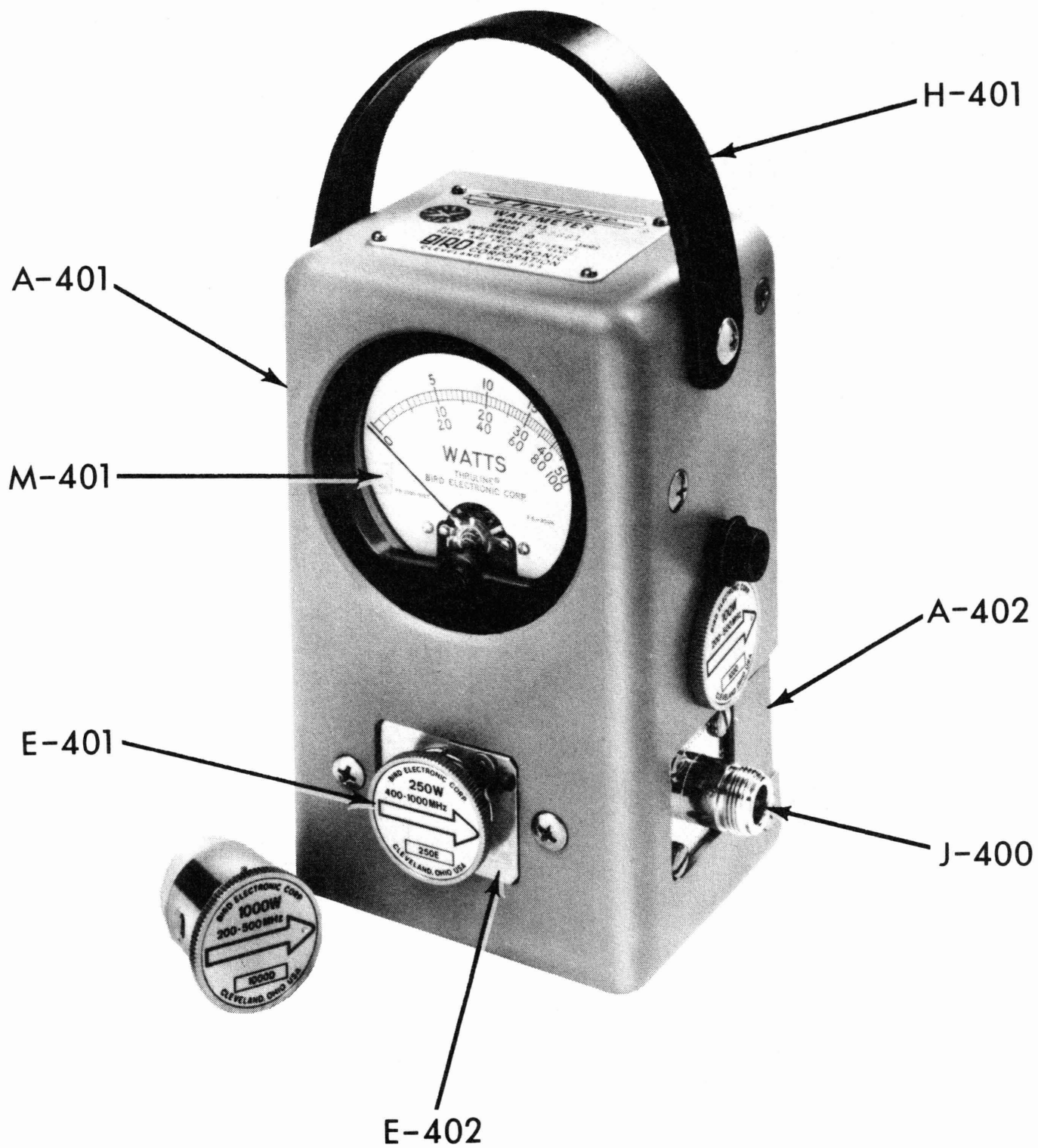
PROBLEM	POSSIBLE CAUSE	REMEDY
Intermittent or inconsistent meter reading	Sticky or defective meter	Replace or return wattmeter to the factory for meter replacement and recalibration.
High VSWR or Reflected Power	Bad load or poor connectors	Replace load, antenna or connectors.
	Shorted or open transmission line	Service or replace line.
	Foreign material in line section or in RF connector bodies	See para 4-3, Cleaning.

4-11. CALIBRATION CHECKS - THRULINE® WATTMETER VS TERMALINE® WATTMETERS

4-12. It is recognized that calibration of absorption wattmeters is difficult and likely to be inaccurate unless comparison is made with a transmission, through, type of standard. With the THRULINE® Wattmeter being of such type, a natural question is: Can a THRULINE® Wattmeter be used to check or recalibrate absorption wattmeters, such as the Bird Electronic Corporation TERMALINE® Wattmeter, when both are rated at ± 5 percent of full scale accuracy? The main question is one of exact power calibration.

4-13. The answer is a qualified yes, although with both instruments being about equally old and known to be undamaged, there is not too much reason to prefer either on probable accuracy. The edge is somewhat in favor of the THRULINE® Wattmeter because each element covers a range of only 2-1/2 to 1 in frequency and will be flatter originally over this range than the TERMALINE® Wattmeter can be held initially over its very much wider, 16.7 to 1, frequency range. Also the THRULINE® Wattmeter will probably exhibit smaller changes with time, because of the narrower frequency range. It is simpler in general design and easier in function (does not have to serve as a power load), and it does not become heated in operation.

FIGURE 4-1. PARTS ILLUSTRATION



4-14. Certainly if the absorption wattmeter has gone for years since its last calibration, or is reasonably suspected of inaccuracy, it may well be calibrated against the THRULINE® Wattmeter as the standard. Rather than use correction factors, one can, with TERMALINE® Wattmeters, make use of the calibration adjustment screws used in factory calibration. These are concealed and not mentioned in the instruction book to discourage tampering. Consult the factory before changing the adjustment.

4-15. If such calibration is undertaken, care and thoroughness are advised.

SECTION V - REPLACEMENT PARTS LIST

5-1. MODEL 43

ITEM	QTY	DWG REF NO.	DESCRIPTION	PART NUMBER
1	1	A-401	Housing assembly	4210-018
2	1	A-402	Cover assembly	4210-005-1
3	1	E-401	Plug-In Element	4250-020
4	1	E-402	Line section assembly	4230-018
5	1	H-401	Carrying strap	8580-003
6	2	J-400	RF connectors	*See Below
7	1	J-411	DC connector assembly	4230-010
8	1	M-401	Microammeter	2080-002
9	1		Replacement meter kit consisting of:	8-000
			1 Meter	2080-002
			1 Cable assembly	4220-097-1
			3 Bumper feet	4220-098
10	1	P-401	DC connector plug	7500-076
11	1	W-403	Cable assembly	4220-097-1
12	2		Turnbutton	4300-015
13	2		Spring washer	5-1147

REPLACEMENTS PARTS LIST [CONT.]

DWG

ITEM	QTY	REF NO.	DESCRIPTION	PART NUMBER
14		2	Pushnut	5-1076
15		4	Rubber stem bumper	5-1388

***Available "QC" Type Connectors**

N-Female	4240-062	LT-Female	4240-018
N-Male	4240-063	LT-Male	4240-012
HN-Female	4240-268	C-Female	4240-100
HN-Male	4240-278	C-Male	4240-110
LC-Female	4240-031	UHF-Female(SO-239)	4240-050
LC-Male	4240-025	UHF-Male(PL-259)	4240-179
BNC-Female	4240-125	7/8" EIA Air Line	4240-002
BNC-Male	4240-132		

SECTION VI - DIFFERENCE DATA SHEETS

6-1. MODEL 4430 THRULINE® WATTMETER

6-2. GENERAL

a. The Model 4430 RF Sampling Wattmeter operates the same as the Model 43 THRULINE® Wattmeter described in this instruction book in all particulars except for the extra provision of the special RF signal sampler probe equipment.

b. The general applications and maintenance procedures for the Model 4430 are the same as those of the Model 43. However, for instructions and specifications directly applicable to the Model 4430, the following information applies.

6-3. Installation - Same as for the Model 43 Wattmeter. Connect RF Sampler output with a suitable cable assembly, having a BNC plug and appropriate RF cable. UG-88E/U, UG-250D/U or equivalent plug, and RG-58C/U (50 ohm) or RG-59B/U (75 ohm) cable would be a common usage. The impedance of the sampler cable should properly match that of the monitoring equipment and be kept as short as conveniently possible.

6-4. Theory of Operation -

a. The RF Sampler, as its name implies, provides a low level signal or sample of the energy being transmitted through the line section of the wattmeter. This signal is available at a Female BNC connector located on the right side of the meter housing, labeled "RF SAMPLE".

b. The signal output level is essentially flat at -53 dB from 10 MHz to 512 MHz, tapering down below 10 MHz to -70 dB at 2 MHz. This type of sample output serves to protect sensitive front-end circuits from unexpected overload and burnout.

c. The RF sampler probe device is fixed to the main line opposite the measuring element socket section and its output is fed to the BNC jack on the upper right hand side of the wattmeter housing. While operating the unit, this sampler output may be fed to any suitable RF signal monitoring device; i.e., frequency counter, spectrum analyzer, or oscilloscope, etc.

6-5. Maintenance - The same general maintenance procedures will apply to the Model 4430 as those described for the basic Model 43 in this instruction book. Other processes pertaining to this model are:

a. To change the sampler probe, remove the back cover, snap off the button at the top of the probe block with a knife edge or sharp screwdriver. Take out the four 4-40 x 1/2 inch screws from the corners of the block, releasing it. The bayonet plug disconnects from the probe by pushing in first with a slight counterclockwise turn, then pulling out.

b. To remove the sampler output cable, use a suitable 5/8 inch flat wrench and unscrew the outside hex nut on the BNC jack; pull the cable out on the inside of the case.

c. This cable is best replaced in its entirety, if required. Its components can be changed by the usual procedures for the BNC and miniature cable plugs.

TABLE 6-1. REPLACEMENT PARTS LIST - MODEL 4430

ITEM	QUANTITY	DESCRIPTION	PART NUMBER
1	1	Wattmeter housing assembly (replaces 4210-018)	4430-011
2	1	Line section assembly consisting of: (replaces 4230-018)	4430-004
		1 Modified line section	4230-006-3
		1 RF sampler assembly	4430-007
		1 Snap button	5-570-2
		1 "QC" Female N connector	4240-062
3	1	RF cable sampler assembly consisting of:	4430-002
		1 Cable (RG-58/U)	5-773-1
		1 MB connector plug, Male	5-245
		1 BNC jack (UG-909/U)	5-953
		1 Brass eyelet	5-414-1

6-6. MODEL 4431 THRULINE® WATTMETER**6-7. GENERAL**

a. The Model 4431 RF Sampling Wattmeter is essentially the same as the Model 43 THRULINE® Wattmeter described in this instruction book in all particulars except for the extra provision of the special adjustable RF signal sampler probe equipment.

b. The basic operations and maintenance procedures for the Model 4431 are the same as those of the Model 43 as described in this instruction book. However, for instructions and specifications directly applicable to the Model 4431, use the information that follows.

6-8. Theory of Operation - The RF sampler, as its name implies, provides a low level signal or sample of the energy being transmitted through the line section of the wattmeter. This signal is available at a Female BNC connector located on the right side of the meter housing, labeled "RF SAMPLE", and the level of this signal can be varied by means of the control knob located on the front of the meter housing. This adjustment is accomplished by means of mechanical linkage connecting the sample adjustment (control) knob to the RF probe, so that turning the knob varies the proximity of the RF probe to the center conductor of the line section. Placing the probe closer (clockwise) to the center conductor increases the coupling and the signal level at the RF sample port, and moving the RF probe away from the center conductor (counterclockwise) decreases the coupling. See Table 6-2 for an approximate guide for the levels of coupling, and for a note on the maximum suggested adjustment of the sampler. In the operation of the unit, the sampler output may be fed to any suitable RF signal monitoring device; i.e., frequency counter, spectrum analyzer, or oscilloscope, etc.

TABLE 6-2. MODEL 4431 - COUPLING DATA

Frequency (MHz)	Maximum	Counterclockwise	
	Sensitivity (Fully Clockwise)	4 Full Turns From Max. Position	7 Full Turns From Max. Position
2	69	(Approximate dB	(Approximate dB
10	57	attenuation.)	attenuation.)
25	46		
50	42		
75	39		
100	36		
200	31		
300		38	
400		34	
500		30	
600		29.5	
700		29	
800		28.5	
900		28	36
1000			35.5
			35

Note - It is important to decouple the RF sampler as indicated above for frequencies above 200 MHz. The basic specifications of this instrument will be maintained with the above settings for the RF sampler. Decouple or turn counterclockwise beyond the above settings as much as possible, when possible.

6-9. Maintenance - The maintenance procedures for this model are essentially the same as for the Model 43 except for the inclusion of the variable probe equipment. It is not recommended that user make repairs on the probe assembly. If the sampler malfunctions, we suggest the unit be returned to the factory. Consult the factory. If for a particular urgency, the user wants to make field replacement of the probe assembly themselves, proceed as follows:

- a. To reach the probe, remove the four 8-32 x 3/8 inch Phillips flat head screws on the sides of the case near the back. Grasp the back cover firmly, by the tabs behind the line connectors, and pull straight backward to remove the back cover.
- b. Use a 1/16 hex socket Allen wrench to loosen and remove the small coupling control knob on the front of the wattmeter, just above the Plug-In Element socket. Remove the two 8-32 x 1/4 inch pan head screws fastening the guide and movable plate assembly to the back of the line section. Restore the control knob to the front of the shaft temporarily, then rotate the shaft counterclockwise until the threaded collar is free of the screw shaft and pull the movable probe plate straight out of the pin and guide bushing. Unscrew the 5/8 hex instrument nut on the BNC connector (outside) and pull the sampler connector inside the case. The probe plate assembly, P/N 4431-003, is now released and may be replaced in its entirety.
- c. The sampler cable (RG-58/U) solid wire center conductor is soldered to the rear stub of the probe piece itself. The cable is secured to the side sleeve of the probe with the same washer and screw parts used in the dc connector plug assembly, P/N 7500-076. It may be removed by unscrewing the threaded sleeve washer, 3/8 hex head, unsoldering the lead tip and pulling out the cable. The probe assembly is formed into the socket and is not replaceable.
- d. Replace by carefully reversing the above procedure. Note - When inserting the threaded control bushing, be sure the alignment pin is properly positioned.

TABLE 6-3. REPLACEMENT PARTS LIST - MODEL 4431

ITEM	QUANTITY	DESCRIPTION	PART NUMBER
1	1	Modified housing (instead of 4210-018)	4431-011
2	1	Guide plate assembly	4431-002
3	1	Movable plate assembly	4431-003
4	1	Line section assembly (instead of 4230-018)	4431-004
5	1	RF cable sampler assembly consisting of:	4431-030
		1 BNC connector, Female	5-953
		1 RF cable - RG58/U	5-773-1
		1 BNC connector eyelet	5-414-1
		1 Washer*	7500-074
		1 Wedge*	7500-080
		1 Seal*	7500-081
		1 Screw*	7500-082
		*Connector parts for probe sleeve	
6	1	Sampler control knob	5-1193
7	1	DC meter cable (instead of 097-1)	4220-097-8

6-10. SERIES 4520 THRULINE® WATTMETERS**6-11. GENERAL**

a. The Series 4520 RF THRULINE® Wattmeter units are essentially the same as the Model 43 Wattmeter, in that their electrical components and performance characteristics are alike. These models are panel mounted for rack-type installation instead of the all purpose portable housing of the Model 43 Wattmeter. Except for the Model 4527, which has an added feature of a Female BNC RF Sampler output connector on the panel, the

data and operating instructions contained in this instruction book are applicable to the Models 4521/22/23/25/26/27 in all respects, except as explained in the following:

b. These units are intended for fixed installation, generally in rack mounts requiring 19 inch panels. According to each of the model types concerned, the various panels are punched out for the component arrangements involved. The first line of the Replacement Parts List attached, lists (per Item A-405) the panel styles for the respective Models 4521, 4522, etc. The remainder of this list carries the replaceable items for each model covered by the "Difference Data Sheet". From the parts list of Section V, only those items that are referred to in this attached parts list, apply herein. Figure 1-1 of this instruction book is not applicable to these units, and figure 4-1 applies only to the extent that the references M-401, E-401, E-402, and J-401 called out coincide with the parts list attached.

6-12. Installation - Four 12-24 machine screws fasten the wattmeter panel in the selected position on a relay rack, using the pattern of tapped holes regularly provided in standard racks. Choose a location for easy reading and operation of the wattmeter; try to place it where the coaxial cable lengths will be short and may be installed without sharp bends. In making connections, avoid the use of angles and adapters as much as possible. Make sure all cable plugs and connectors are screwed on securely.

6-13. Theory of Operation, Operating Instructions and Maintenance Sections -

a. Although the physical configuration of these models is different, the provisions in these sections of the Model 43 Instruction Book are fully applicable.

b. The Model 4527 is electrically identical to the Model 4430, having an RF sampler port, and therefore, the specifications and sampler probe replacement instructions of the Model 4430 also apply to the Model 4527.

TABLE 6-4. REPLACEMENT PARTS LIST - SERIES 4520

ITEM	QTY	DWG REF NO.	DESCRIPTION	PART NUMBER
1	1	A-405	Mounting panel (Comprises: M=meter, E=element socket, S=switch) Model 4521 (1M, 1E) Model 4522 (1M, 2E, 1S) Model 4523 (1M, 1E) Model 4525 (1M, 1E) Model 4526 (2M, 2E) Model 4527 (2M, 2E)	4521-002 4522-006 4523-002 4525-002 4526-004 4527-005
2		E-401	Plug-In Element 1 Model 4521/23/25 2 Model 4522/26/27 (Select per Tables)	2450-020
3	1		Line section assembly	
		E-402	Model 4521/23/25	4230-018
		E-403	Model 4522/26	4522-002
		E-403	Model 4527	4527-002
4	1	J-400	RF connectors	See Section V - Replacement Parts List
5		J-411	DC connector assembly 1 Model 4521/23/25 (Part of E-402) 2 Model 4522/26/27 (Part of E-403)	4230-010

REPLACEMENT PARTS LIST - SERIES 4520 [CONT.]

ITEM	QTY	DWG REF NO.	DESCRIPTION	PART NUMBER
6		M-401	Microammeter	
			1 Model 4521/22/27	2080-002
			1 Model 4523	2150-015
			1 Model 4525	2080-005
			2 Model 4526	2080-002
7	1	O-401	Switch control knob (Model 4522 only)	5-709
8		P-401	Plug connector (part of W-404)	7500-076
			1 Model 4521/23/25	
			1 Model 4522/26/27	
9	1	S-401	Rotary switch (Model 4522 only)	5-634
10		W-404	Cable assembly	
			1 Model 4521/25 (16"L)	4220-097-5
			1 Model 4522 (Harness)	4522-013
			1 Model 4523 (16.5"L)	4523-003-1
			2 Model 4526/27 (16"L)	4220-097-5
11	1	W-405	RF cable assembly (Model 4257 only)	4430-002

6-14. MODEL 4305 THRULINE® WATTMETER

6-15. GENERAL

6-16. The Model 4305 THRULINE® RF Directional Wattmeter is similar to the Model 43 except for the following items:

a. The housing assembly for the Model 4305 is different from the Model 43. The overall physical dimensions of the Model 4305 housing are 4-5/16"L x 4"W x 6-7/8"H including element and bumper feet (110 x 102 x 175 mm). The weight, including the element, is 3-1/4 lb (1.5 kg).

b. The line section has higher power capability and is larger, being 1-5/8 inch in diameter instead of 15/16 inch as in the Model 43, but this is not externally visible.

TABLE 6-5. MODEL 4305 PLUG-IN ELEMENT TABLE

POWER RANGE	FREQUENCY (MHZ)	PART NUMBER
25 kW	0.45-2.5	25KP7
10 kW	2-30	10KH7
5000 W	25-60	5000A7
	50-125	5000B7
2500 W	25-60	2500A7
	50-125	2500B7
	100-250	2500C7
	200-500	2500D7
	400-1000	2500E7
100 W	1100-1800	100K7
50 W	1100-1800	50K7

6-17. The standard Plug-In Element Tables in this book are not applicable and can not be used with the Model 4305 THRULINE® Wattmeter. The only elements available for the Model 4305 are those elements listed in Table 6-5 above.

6-18. The Purpose and Function, Theory of Operation, and Maintenance Sections for the Model 43 are all appropriate to the Model 4305 except for changes mentioned previously.

6-19. The following part numbers differ from those for the Model 43 in Section V of the Parts List.

TABLE 6-6. REPLACEMENT PARTS LIST - MODEL 4305

DWG		DESCRIPTION	PART NUMBER
ITEM	REF NO.		
1	A-401	Housing assembly	4305-003
2	A-402	Cover assembly	4305-011
4	E-402	Line section assembly	4305-005

The Model 4305 THRULINE® Wattmeter does not have provisions for holding spare elements in the sides of the housing.

6-20. MODEL 4330/31 THRULINE® WATTMETER

6-21. GENERAL

6-22. The Model 4330/31 is very similar to the Model 43 and all the instructions and provisions apply except as outlined below:

- a. The Model 4330/31 is a low power indicating device with full scale direct reading levels of 200 and 800 milliwatts.
- b. This model uses special 0.2 and 0.8 watt dual-range elements that cover frequency ranges from 60 to 2300 MHz. There are 13 of these elements to choose from as listed in the table below. Standard higher power elements must not be used with the Model 4330/31.

6-23. With these low power type elements, the discrete frequency band widths are considerably less than the usual 2.5:1 ratio for standard higher power elements. These band widths (ratios) vary, but tend to be broad in the middle frequencies of the overall range and becomes narrow at the ends. Likewise, the relative response fall off beyond the stated bands will have to be considered as somewhat greater than depicted on the 10 W element curve in figure 4-2. To maintain accuracy, it is important to have operating frequencies within those stated. A table of available element types for use only with the Model 4330/31 Wattmeter is given below.

TABLE 6-7. MODEL 4330/31 PLUG-IN ELEMENT TABLE

PART NUMBER	FREQUENCY RANGE MHz	PART NUMBER	FREQUENCY RANGE MHz
4330-060	60-80	4330-425	425-850
4330-080	80-95	4330-800	800-950
4330-095	95-125	4330-950	950-1260
4330-110	110-160	4330-1100	1100-1800
4330-150	150-250	4330-1700	1700-2200
4330-200	200-300	4330-2200	2200-2300
4330-275	275-450		

6-24. The elements for the Model 4330/31 have a dual power range. The slide switch on the face of the element is moved sideways to select either 800 mW or 200 mW full scale deflection as indicated by the element nameplate. The scales on the meter dial coincide with the position selected. For protection of the meter, always select the higher value first. Do not switch to the lower position when a higher power is indicated in the direction selected.

6-25. The following parts are applicable to the Model 4330/31 and are different from those listed for the Model 43 in Section V. All other parts not listed here are applicable.

TABLE 6-8. REPLACEMENT PARTS LIST MODEL 4330/31

DWG		DESCRIPTION	PART NUMBER
ITEM	REF NO.		
1	A-401	Housing assembly	4330-004
3	E-401	Plug-In Elements per above table	4330-020
8	M-401	Microammeter 10uA full scale 3-1/2" rectangular	2160-027
11	W-403	Meter cable assembly 33" cable e/w spade lugs and dc connector (P-401)	4220-097-12

6-26. MODEL 43P PEAK WATTMETER

6-27. INTRODUCTION

6-28. The Bird Model 43P THRULINE® Wattmeter is capable of measuring peak power in AM, SSB, and certain limited pulse applications. It also possesses the Model 43's ability to measure CW power (no amplitude modulation) with just the press of a button.

6-29. No special elements are required for peak power measurements. However, element power rating must match the peak power to be measured. For example, if power output peaks of 1000 watts are to be measured, a 1000 watt element must be used in the line section port.

6-30. SPECIFICATIONS FOR BIRD MODEL 43P THRULINE®
WATTMETER

RF Frequency Range 0.450-2300 MHz, depending
on element selected.

RF Power Range 100 mW to 10 kW,
depending on element
selected.

Accuracy CW mode ±5% of full scale
PEP mode ±8% of full scale

When measuring rectangular pulse power, the following parameters must be
observed: Duty cycle - 2% minimum
Rep. rate - 100 pps minimum
Pulse width - 200 u sec. minimum

SPECIFICATIONS FOR BIRD MODEL 43P THRULINE® WATTMETER [CONT.]

Power Requirement	(2) 9 V alkaline batteries (NEDA 1604)
Battery Life	Approx 48 operating hours

6-31. OPERATION

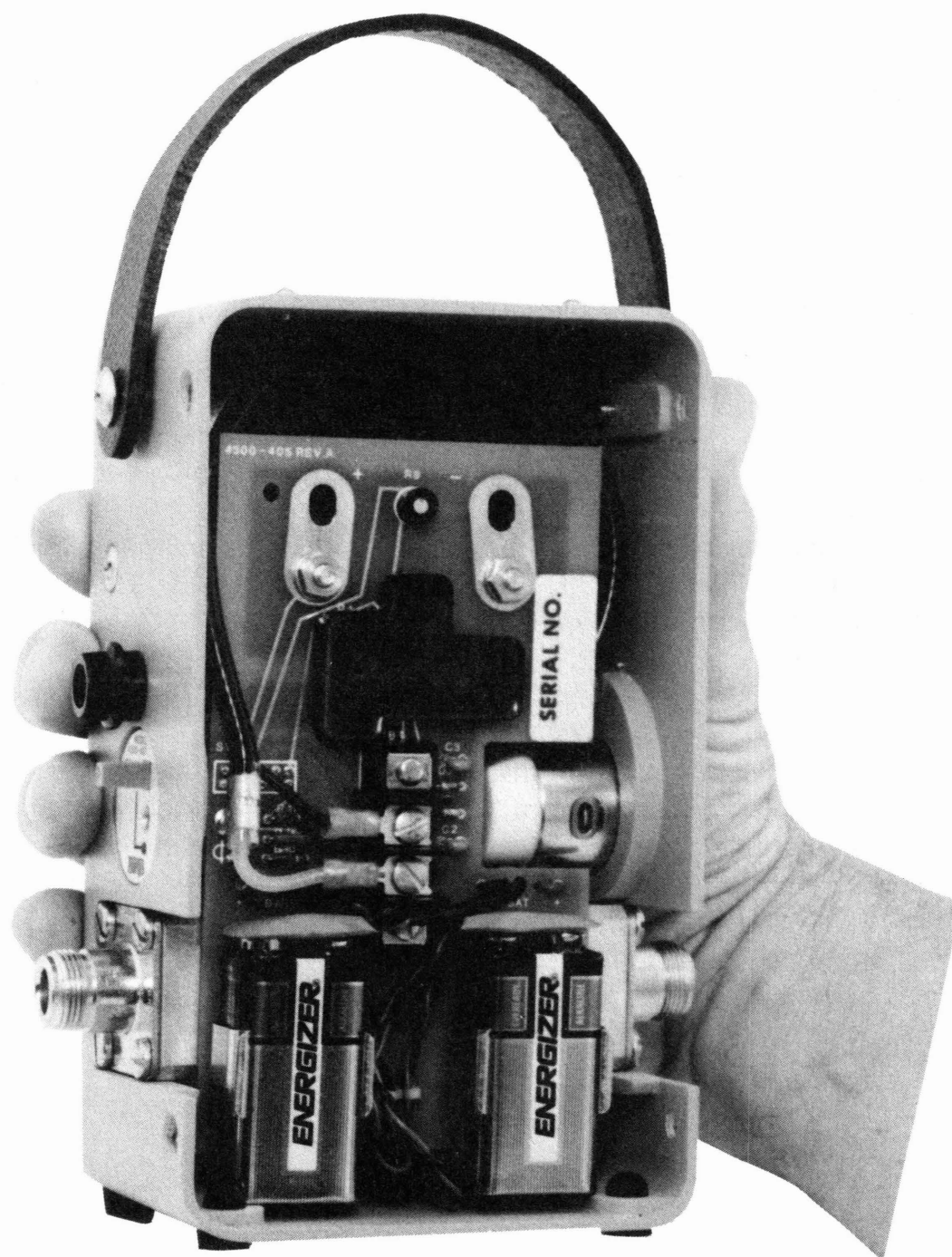
6-32. There is a PUSH ON/PUSH OFF switch on the side of the meter housing that is to your right as you face the unit. To read peak power, push the switch in. Notice that the red LED is lit. The unit is now ready to indicate peak power.

6-33. To read CW power, i.e. no AM modulation, push the switch again to the OFF position. Notice that the red LED is no longer illuminated. The unit will once again function to indicate CW power.

6-34. PEAK DETECTOR RESPONSE

6-35. The electrical time constant of the peak detector circuit is set at one second, although the actual response time may be slightly longer than this due to meter damping. Therefore, a short delay may be noticed between the time that the transmitter is energized, and the meter reading stabilizes. This delay will also be noticed upon transmitter de-energization as the meter needle sweeps back to zero. Also, the meter reading may be expected to waver approximately 2-3 minor scale divisions when voice modulation is used as the peak detector attempts to follow peak power variations associated with voice modulation.

FIGURE 6-1. MODEL 43P INSIDE VIEW



6-36. MODEL 43P PEAK CALIBRATION

6-37. If it is felt that the peak readings are questionable, or for any reason recalibration is required, proceed as described below. The rear cover must be taken off. Remove the four 8-32 Phillips flat head screws that secure the rear cover. They are located two on either side of the meter housing. Pull the cover straight off. Refer to figure 6-1 for the following instructions:

- a. Insert the Model 43P between an RF (CW) signal source and a 50 ohm load. Insert an element for the appropriate power and frequency range into the Model 43 and turn the element in the direction to read forward power.
- b. Place the mode switch on side of the Model 43P in the CW position (LED off). Turn on the signal source. Adjust power to give a stable reading on the Model 43P Wattmeter in the upper half of the scale.
- c. Switch to the PEAK mode (LED on). The RF power reading should remain the same. If it does not read the same, adjust potentiometer (R9 - top center of the PC board) until the PEAK reading is the same as the CW reading. When the CW and PEAK readings are the same, calibration is complete.
- d. Replace the back cover, using the four 8-32 Phillips flat head screws.

6-38. MAINTENANCE

6-39. Maintenance of the Model 43P in general will be the same as for the Model 43 except for battery replacement.

6-40. If the unit does not function properly in peak mode, or calibration cannot be achieved, the batteries may be low. Replace the batteries with new ones, preferably alkaline or lithium type. The batteries fit very tightly in their retaining clips and may have to be pried out one at a time (see figure 6-1).

From 2 to 2300 MHz and from 25 milliwatts
to 250 kilowatts in 50 ohm coaxial line systems.

**TERMALINE®
ABSORPTION
WATTMETERS
LOAD RESISTORS
CALORIMETERS**

**THRULINE®
DIRECTIONAL
MONITORING
WATTMETERS**

**TENULINE®
ATTENUATORS**

**COAXWITCH®
SELECTOR
SWITCHES**

COAXIAL RF FILTERS

**SENTRILINE®
FILTER-COUPLEDERS**

BIRD